Irradiation histories of CAIs and LL3/CB chondrules.

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Introduction: The solar and galactic cosmic ray irradiation recorded by chondrules and refractory inclusions (CAIs and AOAs) can provide unique information on their formation, transport and storage histories. To explore the irradiation histories of these objects, we have developed novel analytical protocols to accurately measure Ca/K ratios and K-isotopes by thermal ionization mass spectrometry [1]. The low abundance of ^{40}K relative to ^{39}K makes the ^{40}K/^{39}K ratio a sensitive indicator of spallation and secondary neutron irradiation, where efficient production of ^{40}K occurs during proton, alpha and neutron reactions on calcium targets through ^{43}Ca(p,a)^{40}K, ^{44}Ca(p,n+a)^{40}K ^{40}Ca(a,x)^{40}K and ^{40}Ca(n,p)^{40}K.

Samples: We selected well characterized CAIs and AOAs from the Efremovka carbonaceous chondrite (CV3red) and three spatially ascociated chondrules from the NWA 5697 ordinary chondrite (LL3). The LL3 chondrules have variable U-corrected Pb-Pb dates and ^{54}Cr compositions [2], suggesting lateral transport and storage of these objects in the solar protoplanetary disk for at least ~2 Myr prior to accreting on the NWA 5697 parent body. We also analyzed chondrules from several members of the Gujba (CB) meteorite.

Results: All material analyzed show large (i.e. permil to percent) positive ^{40}K anomalies that broadly correlate with Ca/K ratios, consistent with formation from Ca-targets. The ^{40}K anomalies in the LL3 chondrules vary with their absolute Pb-Pb dates, such that the oldest chondrules register the largest doses. Although the ^{40}K anomalies must contain a component that formed during recent meteoroid phase, the variations between such closely spaced (≤ 5cm) chondrules must reflect differences in their individual preaccretion histories. At face value, the correlation with age is consistent with a monotonic irradiation source, suggesting that ^{40}K anomalies were generated during storage in the protoplanetary disk, possibly from exposure to galactic cosmic rays and ascociated secondary neutrons. Efremovka CAIs also show ^{40}K anomalies in excesses of meteorid phase exposure models, although these are hard to quantify due to uncertainties in the physical placement within the Efremovka meteorite. The doses recorded by both CAIs and LL3 chondrules suggest exposure to ionizing irradiation conditions that conflicts with models of strict dead zone storage. In contrast, Gujba chondrules within individual members record similar doses, suggesting a dominant meteoroid phase exposure with limited if any pre-accretion exposure, consistent with rapid accretion following formation in an impact plume[3].

Future work: We are working towards better constraining the meteoroid phase exposure in order to accurately access pre-accretion signatures, in addition to conducting depth profiles to discriminate between neutron and energetic solar or galactic charged particles irradiation.

References: [1] Wielandt D. and Bizzarro M. 2011. *Journal of Analytical Atomic Spectrometry* 26:366-377 [2] Connelly J. et al. 2012. *Science* 338:651-655 [3] Krot, A.N. et al 2005. *Nature* 436:989-992.